Design and Cost Analysis of Rural and Urban Toilet

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Abstract

Providing sanitation is India remains a huge challenge. This study explores the difficult that occur due to sanitation in rural and urban India through the approach of conducting a field survey in the areas. The survey results are analyses and solution of the problem is provided. The solution involves providing an ecological sanitation (ECOSAN) TOILET. AutoCAD drawing of the designed toilet are provided for better understanding. The response of public on the design toilet suggested was studied with help of another survey to know the preference of the people. Along with design the cost of conventional toilet posed a great challenge for successful sanitation in rural areas. This study aims to reduce the cost of toilet construction by removing pit system as well as changing the superstructure material. The cost comparison of various toilet and those with different superstructure material is presented. The initial cost of EcoSan toilets, which is about Rs. 10520, is slightly higher than ordinary pit latrines or offset double pit latrines, EcoSan toilets provide benefits in terms of fertilizer. A financial analysis of cost and benefits of EcoSan toilets indicates that the pay-back period for an EcoSan toilet is 6 years, Benefit To Cost Ratio of 1.17(At I=10%) and the Financial Internal Rate of Return (FIRR) is 14.527 percent. However social acceptability of our designed toilet remains uncertain. In a Comparison matrix, which includes four different latrine designs, the designed ECOSAN receive the highest scores (21 out of 27) for a given set of design and evaluation criteria. Potential areas for cost reductions and design improvements are identified.

Keywords- Rural, Urban, Toilet, ECOSAN.Design, Costing, Survey

I. INTRODUCTION

Toilets are an important part of our life, but the efficiency of toilet needs improvement. Also the number of toilet must increase. Both economic and design must be targeted for successful sanitation project and provide a better hygiene for the society. The objectives are to provide an alternative design for rural and urban toilets and to provide cost effective toilets. And need of the study is for engineering, cultural and environmental reasons and also so poor peoples can have their basic need fulfilled with reduction of health hazards.

II. PROBLEM SURVEY

Survey was done to know the current level of toilet and problem faced by people in both the rural and urban areas of Surat and Navsari city.
For rural area we have selected 14 villages where there is problem related to toilet or have no toilets. The villages were as follow:- Sarbhon ,Vanesa ,Mahuva ,Bhata ,Afva ,Aada ,Bardoli (opp .civil court) ,Isroli, Vankaner ,Saroli ,Kanai ,Bhata-lav ,Indu ,Kadiya
For urban area we have selected public area and slum colony where there is problem related to toilet or have no toilets. The areas were as follow:-Adajan area (Surat), Udhna and Parvatpatia (Surat), Navsari area
Survey was done and question related to access to toilet along with topic like longevity and durability, local availability of material, comfort and privacy ,maintainability, scale ability, social acceptability ,cost effectiveness, health were asked.
Survey results were as followed:-

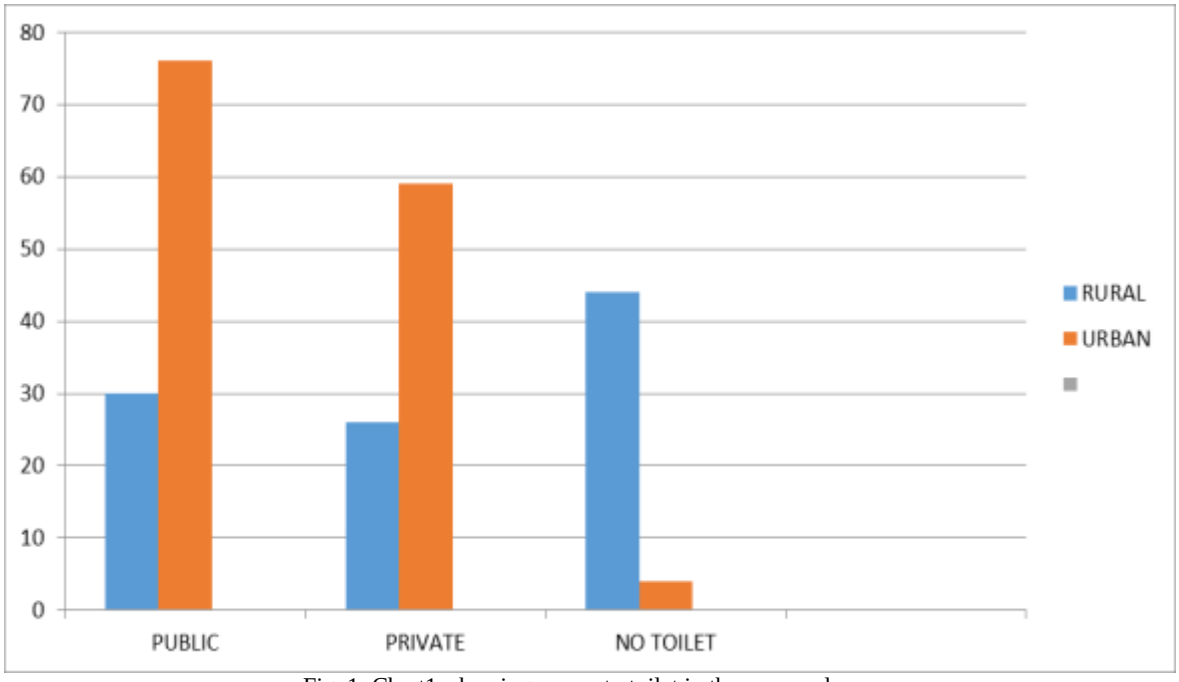

Fig. 1: Chart1: showing access to toilet in the surveyed area

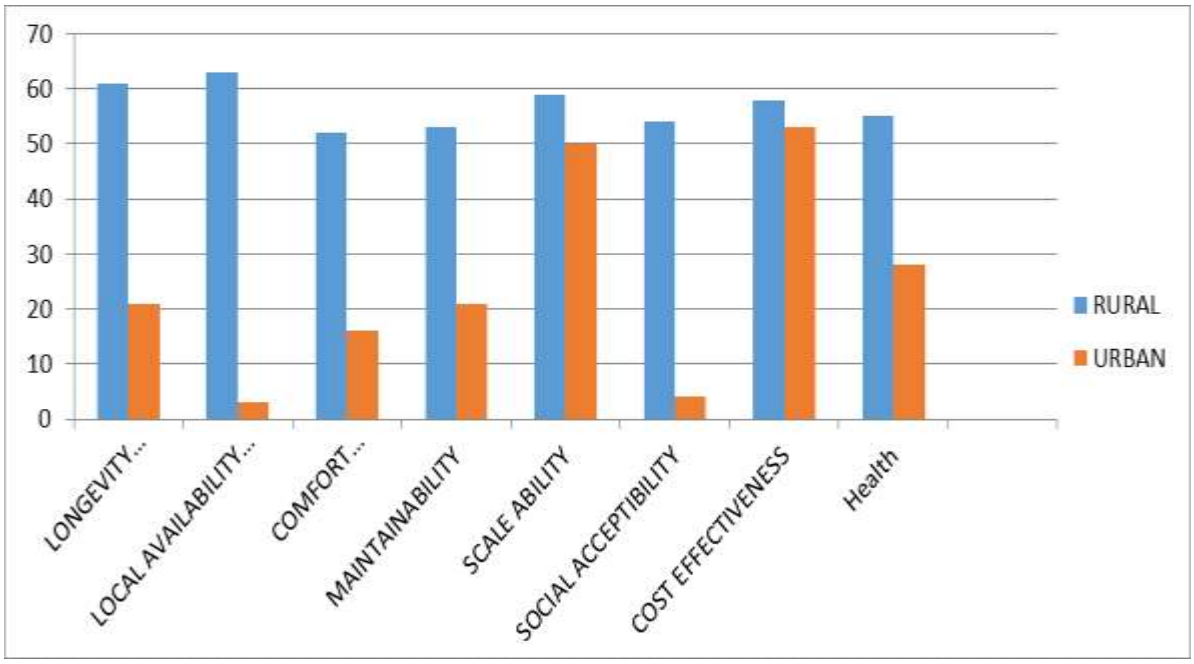

Fig. 2: Chart 2: showing problem with toilet in the surveyed area

III. SOLUTION

People in rural area had many problems with toilet while those in urban area had less number of problems. But there is a solution that can accommodate problems of both rural and urban areas. The use of ECOSAN toilet is the answer to all problems. Ecosan allow for the source separation of urine and faeces through the use of a specially designed seat or squatting pan, generally referred to as the user interface. Urine diversion serves a number of important functions including reducing odour and simplifying the excreta management process.

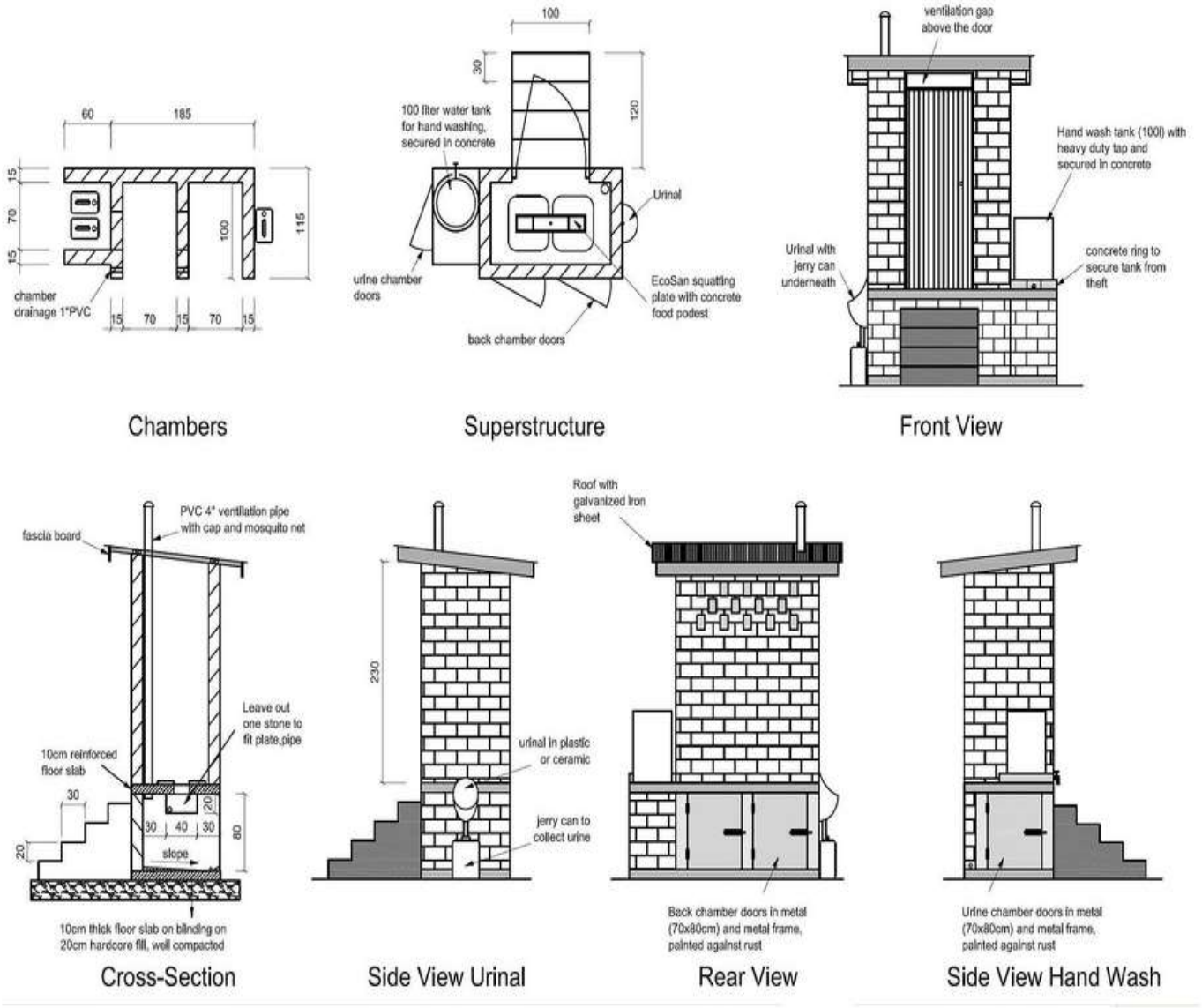

Fig. 3: Image 1: showing double vault ecosan toilet (source: www.flickr.com/photos/gtzecosan/4542381497)

In our toilet we are recommending use of container for collecting the solid waste. The whole idea of removing pit either below our above the surface is to save ground water from the leachate as well reduce costing. Urine is separated at the user interface, drained through a piping system and infiltrated into the soil for disposal, or collected, stored and sanitized in containers for use as a fertilizer. Faecal matter is collected into a ventilated vault directly below the user interface. Following defecation, the user covers the fresh faeces with a small volume of dry cover material in order to absorb moisture, control initial odour and prevent insect infestation. The faeces vaults may be located aboveground or below ground, depending on the chosen faeces management method
SOURCE: ECOSAN review, GTZ-EU
Calculation for required dehydration CONTAINER volume for a 10-person household with high fiber vegetable diet for six month storage.
Cover materials: assumed daily average 0.08 kg/p/day ((data as per WHO standards)
Density of faeces assumed to be 1 kg/l
Storage duration: six months after last use
Faeces production:
5 Adults x 0.4 kg/day = 2.0 kg/day
5 Children/elderly x 0.15 kg/day = 0.75 kg/day
Faece produce per day = 2.80 kg/day (approx.)
Faecal weight = 84 kg/month (approx.)
Accounting for absence (-10%) = - 9 kg/month
Net faecal weight = 75 kg/month

Faecal weight for half year (x 6 months) = 450 kg/half year (approx.)
Moisture loss (- 30%) = -140 kg/half year (approx.)
Cover material = 140 kg/half year
Entire family per half year = 450 kg/half year (approx.)
Safety margin + 20% = 90 kg/half year (approx.)
Required CONTAINER volume = 540 kg/half year
Required CONTAINER volume = 540 litre
Check in design
LBH=100*70*80
= .560 m^3
= 560 Liters
So container of 540 l could easily be accommodated with boundaries on left on sides for easy operations.
Urine tank size

$$V_{storage} = N_{(users)} \cdot \rho_{(urine)} \cdot t_{(storage)} \cdot f_{(time\text{-}fraction)}$$

N users = number of users
ρ urine = specific urine production per person
(~ 1.5 L/cap/d of urine if the user is at the premises 24 hours per day)|
t storage = desired storage time
f time-fraction = fraction of time that the users stays at the premises where the toilet is.
Typical design criteria for a storage tank are 360 L of urine per person per year (if they spend
2/3 of their time at the premises) and a storage time of one Month
If transportation occurs manually, the collection tanks should not be larger than 20 L which equals 20 kg when full .
Check in design
N=10, ρ =1.5, T= 15, F= 0.67
V= 10*1.5*15*0.67 =150 L
SIZE OF AREA ALLOTED IN DRAWING
LBH= 70*60*80
= .340 m^3
= 340 L
In design we can easily accommodate two tanks of 150 liters capacities which can store urine for 15 days alternatively.

IV. COSTING AND FINANCIAL ANALYSIS

A. Costing Of Single Door Double Vault with Brick Superstructure

Table 1: Showing Costing Of Single Door Double Vault with Brick Superstructure

Sr no.	*Particulars*	*Units/no's*	*Unit rates*	*Amount*
1	*Earth work excavation*	*1*	*100*	*100*
2	*Boulders*	*40*	*3*	*120*
3	*bricks*	*850*	*5*	*4250*
4	*Cement*	*3 bags*	*300*	*900*
5	*Sand*	*50 cubic ft*	*10*	*500*
6	*Slab cost(squatting, roof, detaching)*	*6*		*1600*
7	*Door cost 5'*2'6"*	*1*		*400*
8	*PVC pipes material*			*450*
9	*Mason wages -man days*	*2*	*300*	*600*
10	*Unskilled labours–man days*	*4*	*250*	*1000*
11	*Material transportation*			*100*
	Total			*10020*

With change of superstructure material cost could be lowered. Other than brick materials like mud block stone, cement stone, tin sheet, and hollow block could also be reduced.

Table 2: Showing Costing of Single Door Double Vault with Different Superstructure Material

Material	*Cost*
Mud Block Stone	*10200*
Cement Stone	*8650*
Tin Sheet	*8720*
Hollow Block	*8140*

B. Financial Aspect

Costs and financing play an important role in planning sanitation schemes and selecting appropriate technologies. This section summarizes some of the studies related to the financial aspects of EcoSan toilets and presents a financial analysis for EcoSan toilets in Surat. Normally, financial aspects of projects are assessed using financial or economic analysis. Financial analyses assess the costs borne by the end users and the direct revenue from the project, while economic analyses also assess the overall costs and benefits to the society as a whole. The analysis is done over the expected lifetime of the facilities.

The following key assumptions are made for financial analysis:

- The construction time for EcoSan toilets is less than one year.
- All costs and benefits are expressed in April 2016 prices.
- The generation of benefits is the values of urine and faeces collected in the toilet.
- Financial analysis of the toilet is carried out over a period of 10 years.
- The residual value of the civil structure of the toilet is assumed to be 60 percent of initial cost in the tenth year.

1) Project costs

The total construction cost, based on market prices in April 2016, is estimated at Rs.10520.00

2) Basic calculations

Calculating for single door double vault ECOSAN toilet.

- The total construction cost =INRs. 10020
- Take 5% extra =500
- The Final construction cost INRs. 10520 (approx.)
- The total cost of the additives = 300 per annum
- The total cost of the activities/maintenances = 400 per annum
- Total cost to run the toilet=INRs. 700 per annum

Liters of urine =550 /per year (data as per WHO standards)

- The volume of urine contains, on average,
- Nitrogen = 4kg
- Phosphorus = 400 grams
- Potash = 1 kg

Thus an average family of six members family produces

- Nitrogen = 24 kg
- Phosphorus = 2.4 kg
- Potash= 6kg

The average prices of nitrogen, phosphate and potash on the market in April 2016, as calculated based on their contents in

- Urea (nitrogen) = INRs. 48.56/Kg
- DAP (phosphate) = INRs. 58.36/Kg
- Muriate of potash = INRs. 43.58/Kg

So total value generated from urine from,

- Nitrogen = 1165
- Phosphate = 140
- Potash = 261
- Total = INRs. 1570 per year (approx.)

Income from faeces production

- Annual production of faeces = 350 kg
- The value of soil conditioner (compost) in Surat is (estimated) = INRs. 3/ kg
- The annual total estimated value of the soil conditioner = INRs. 1050

Total annual income = INRs.2620

Total annual expenditure per year= INRs. 700

Net income = 1920

Total cost of project = INRs. 10520

Source: pg. 114-120, NCEES supply reference handbook, 8th edition, 2nd revision

Payback Period

The 'Pay Back Period' indicates when the investors will obtain their investments from the operation of the project

Payback Period = Cost of Project / Annual Cash Inflows

=5.47 yrs

= 6 yrs (approx.)

3) Benefit /Cost Ratio

Benefit/Cost Analysis Decision Aid is based on a common financial decision model for evaluating projects or proposals. B/C ratio must be greater than one for project to be accepted. PV stands for present value.

I=10%

Table 3: Showing the Calculated Present Value Over 10 Years Span

Year	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Benefits	*0*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*5112*
Disc Factor I =10%	*1.1^0 =1*	*1.1*	*1.21*	*1.33*	*1.46*	*1.61*	*1.77*	*1.94*	*2.14*	*2.35*	*2.59*
PV Benefits	*0*	*2381*	*2165*	*1970*	*1794*	*1627*	*1480*	*1350*	*1224*	*1114*	*1973*
Cost	*10520*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*0*
PV Cost	*10520*	*636*	*578*	*526*	*480*	*434*	*395*	*360*	*327*	*297*	*0*

Sum benefits = 17078

Sum costs = 14553

B/C = 1.17 >1…….ACCEPTABLE

4) Financial Internal Rate of Return (FIRR)

The FIRR is an indicator to measure the financial return on investment of an income generation project and is used to make the investment decision.

The FIRR is obtained by equating the present value of investment costs (as cash out-flows) and the present value of net incomes (as cash in-flows) and thus finds out the break-even interest rate, "i"

In general, the decision rule is as follows:

– If FIRR > MARR, then, accept the project.
– If FIRR = MARR, then, remain indifferent.
– If FIRR < MARR, then, reject the project.

The present rate of interest for loan on construction work is 9.5% (SBI rate)

So MINIUM ACCEPTABLE RATE OF RETURN (MARR) = 9.5%

Initial Investment =INRs. 10520

Annual Maintenance= INRs. 700

Annual Earning= INRs. 2620

Net Annual Earning = INRs. 1920

Depreciation Value = INRs. 200/Year

Total Depreciation in 10 Yrs = INRs. 2000

Net Worth of Infrastructure = INRs. 8520

Salvage Value at 10th Year = 60 Percent of the Present Value of the Infrastructures

= INRs. 5112

At I=12%

Table 4: Showing the Calculated Present Value Over 10 Years Span

Year	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Benefits	*0*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*5112*
Disc Factor I =12%	*1.12^0 =1*	*1.12*	*1.25*	*1.40*	*1.57*	*1.76*	*1.97*	*2.21*	*2.47*	*2.77*	*3.10*
PVBen	*0*	*2340*	*2096*	*1871*	*1668*	*1488*	*1330*	*1185*	*1060*	*945*	*1650*
Cost	*10520*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*0*
PVC	*10520*	*625*	*560*	*500*	*445*	*397*	*355*	*316*	*283*	*252*	*0*

Sum benefits = 15613

Sum costs = 14253

– Difference between the benefit and cost =NET PRESENT VALUE=1360

TAKE 12.5 %

Table 5: Showing the calculated present value over 10 years span

	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Benefits	*0*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*5112*
Disc Factor I =12%	*1.125^0 =1*	*1.125*	*1.265*	*1.423*	*1.600*	*1.800*	*2.027*	*2.280*	*2.565*	*2.886*	*3.247*
PVBen	*0*	*2328*	*2070*	*1840*	*1637*	*1455*	*1292*	*1149*	*1020*	*910*	*1575*

Cost	*10520*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*0*
PVC	*10520*	*622*	*553*	*492*	*437*	*388*	*345*	*307*	*272*	*242*	*0*

Sum benefits = 15276
Sum costs = 14178
DIFFERENCE =1098
TAKE 14.5 %

Table 6: Showing the calculated present value over 10 years span

Year	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Benefits	*0*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*5112*
Disc Factor I =14.5%	*1.145^0 =1*	*1.145*	*1.311*	*1.500*	*1.718*	*1.968*	*2.253*	*2.580*	*2.954*	*3.382*	*3.873*
PVBen	*0*	*2288*	*1998*	*1746*	*1525*	*1331*	*1162*	*1015*	*887*	*774*	*1320*
Cost	*10520*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*0*
PVC	*10520*	*611*	*533*	*466*	*407*	*355*	*310*	*271*	*237*	*206*	*0*

Sum benefits = 14046
Sum costs = 13916
DIFFERENCE =130
TAKE 14.8 %

Table 7: Showing the calculated present value over 10 years span

	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Benefits	*0*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*2620*	*5112*
Disc Factor I =14.8%	*1.148^0 =1*	*1.148*	*1.317*	*1.512*	*1.736*	*1.993*	*2.290*	*2.627*	*3.016*	*3.463*	*3.975*
PVBen	*0*	*2282*	*1990*	*1732*	*1509*	*1314*	*1144*	*997*	*868*	*756*	*1286*
Cost	*10520*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*0*
PVC	*10520*	*609*	*531*	*462*	*403*	*351*	*305*	*266*	*232*	*202*	*0*

Sum benefits = 12592
Sum costs = 13881
DIFFERENCE = -1289

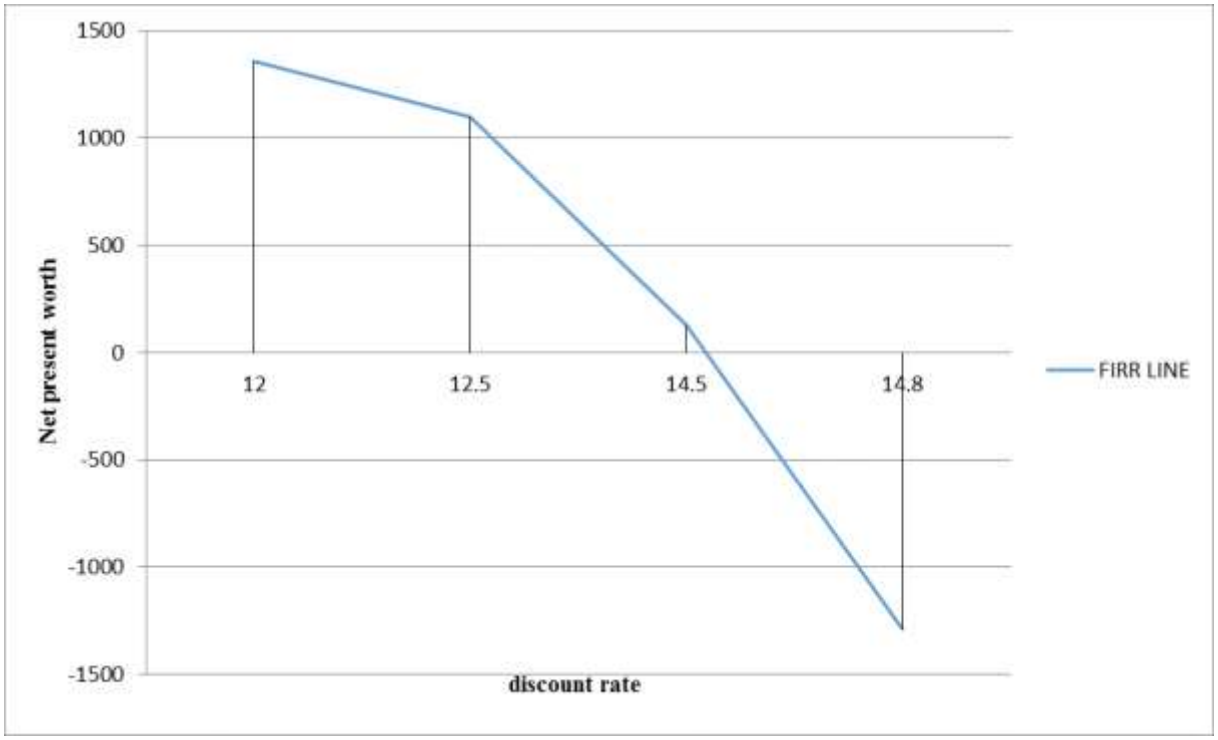

Fig. 4: Graph 1: showing net present worth v/s discount rate

The calculated FIRR is 14.027 percent. The investment is worth it since the present average interest rate for a commercial bank home construction loan is 9.50 percent. This means that the family who construct an EcoSan toilet from a bank loan will be able to pay the loan if the family sells urine and soil conditioner at market value.
FIRR (14.527%) > MARR (9.50%)……..PROJECT ACCEPTABLE

V. SOLUTION SURVEY

After the problem survey and analyzing the problem, a well detailed solution was prepared. The design was further drawn in AutoCAD software. Along with the design a very appropriate cost were carried out and financial aspect of the project was considered.

But it was important to take the design and cost obtained to the people and asks for their preference weather they prefer the design or not, as it the people who are supposed to be the end user. So a survey was done in the same areas as the problem survey so obtain the review of the people.

A. Survey Results

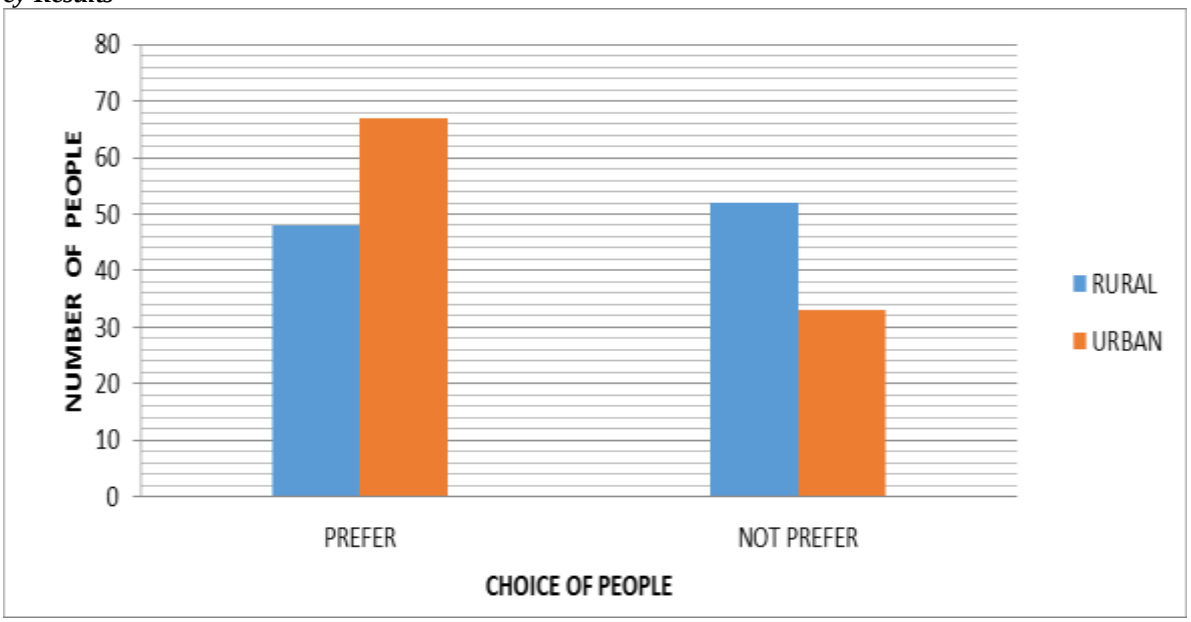

Fig. 5: Chart 3: showing choice of people over our toilet in the surveyed area

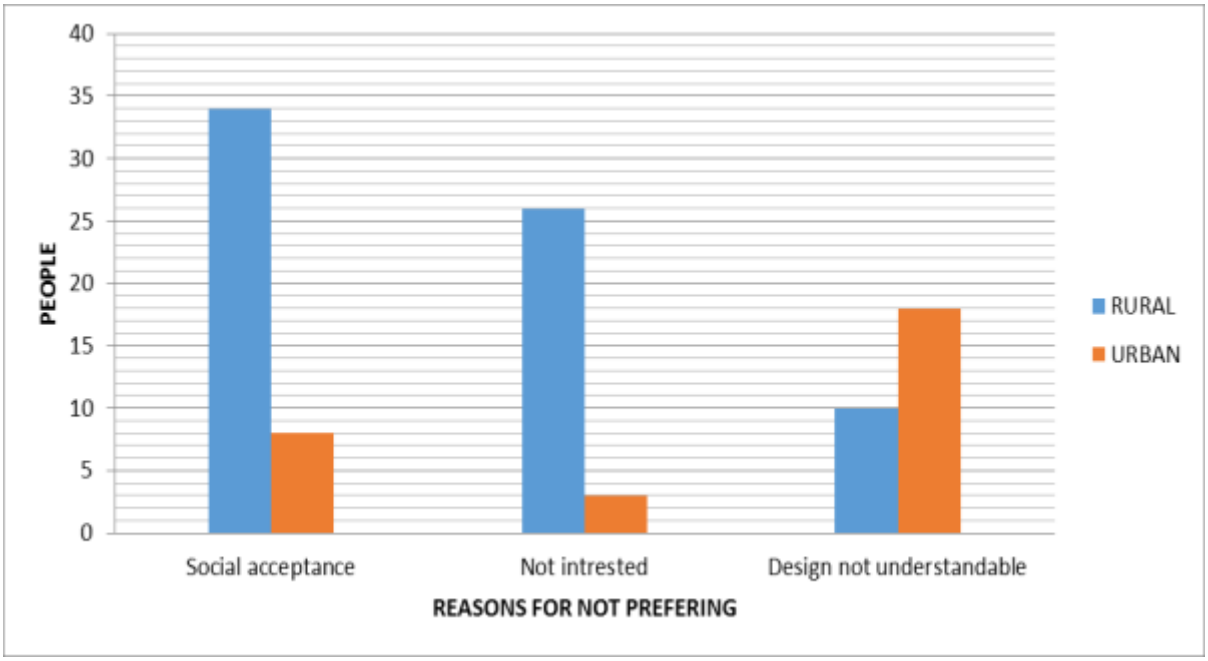

Fig. 6: Chart 4: showing reason for not preferring out toilet

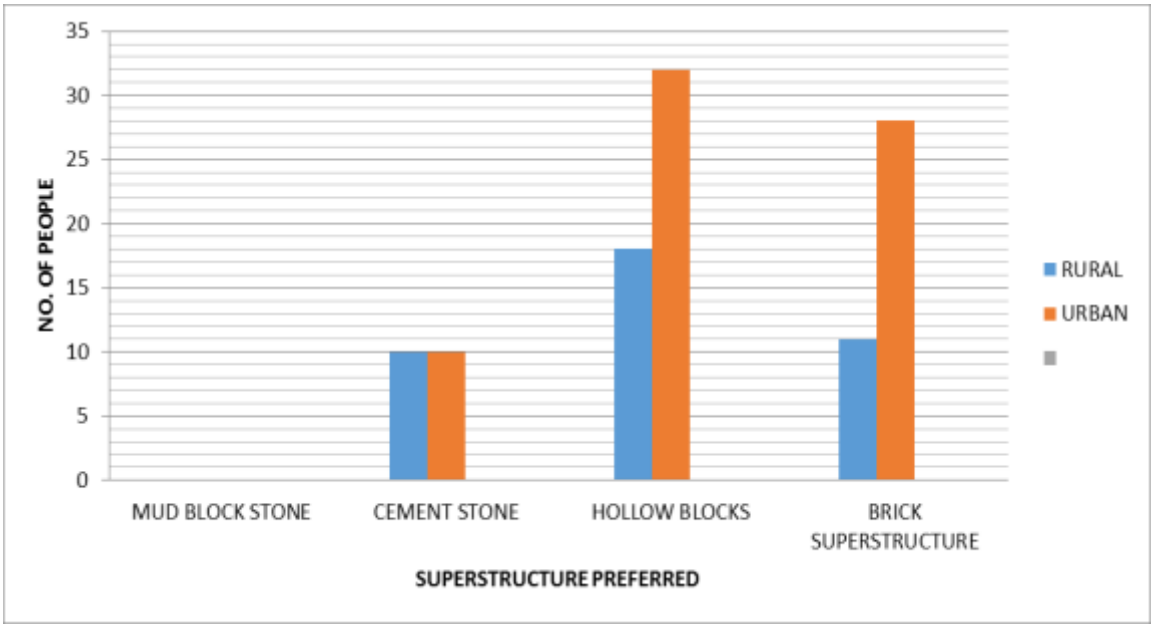

Fig. 7: Chart 5: showing preferred superstructure

VI. CONCLUSION

A. General

1) Using the design criteria specified, a comparison matrix was developed by assigning scores (from 1=worst to 3=best) to each category.
2) This comparison matrix is intended as a rough guide for illustrating the advantages and disadvantages of the four different designs Comparison matrix table.

Table 8: Showing the comparison matrix

	Single-Pit VIP Latrine	*Twin Pit Pour Flush*	*ECOSAN with pit*	*Designed ECOSAN*
Longevity And Durability	*3*	*3*	*1*	*2*
Materials Availability	*2*	*2*	*1*	*1*
Comfort And Privacy	*1*	*1*	*2*	*3*
Simple O&M	*1*	*2*	*2*	*3*
User/Social Acceptance	*1*	*2*	*2*	*3*
Scalability	*1*	*1*	*2*	*2*
Cost-Effectiveness	*1*	*2*	*2*	*3*
Ease Of Construction	*1*	*1*	*2*	*3*
Proneness To Flooding Risks	*1*	*1*	*1*	*1*
Total Score	*12*	*15*	*15*	*21*

B. Scoring

1) Durability

Ventilated pit toilet (VIP): It Last for many years so score= 3
Twin pit pour flush (TPPF): It last for many years so score= 3
Ecosan (E): Cheap material are used to reduce cost which affects life so score= 1
Designed eco-san (DE): Variety of material are used overall which results in increase in life so score =2

2) Materials Availability

V.I.P: Little high score as easily available so score= 2.
T.P.P.F: Material available easily so score= 2.
E: Toilet diverting seat not readily available so score 1.
DE: Toilet seat as well as superstructure not readily available (working on making locally available seats) so score= 1.

3) Comfort and Privacy

All have sufficient comfort and privacy.
V.I.P: They are often smelly and nuisance to local villagers so score =1.

TPPF: Difficult to change the valve and excavating the pit after they are completely full so score =1.
E: Less smelly although has cleaning issue so score= 2.
DE: Less smelly as dry decomposition and easy cleaning so score= 3.

4) User/Social Acceptance

VIP: Most easily and readily accepted so score= 3.
TPPF: Easily accepted so score= 3.
DE: Very less accepted and it is a biggest challenge for this toilet due to handling of fecal matter so score =1.
E: More accepted than modified eco-san yet handling of fecal matter is a issue so score= 1.

5) Simple O&M

All have operational constraints.
V.I.P: Need to empty tank after few years so score= 1.
T.P.P.F: Better than VIP as two large tanks are provided but no special methods are available to excavate the pits so score =2.
E: Better than VIP as no digging out pits yet needs to remove the solid waste occasionally so score= 2.
DE: Regular cleaning are easily possible and operation are easy but takes some time to be learnt so score= 3.

6) Cost-Effectiveness

V.I.P: It is not expensive in construction but requires high maintenance so overall increase in cost so score=1.
T.P.P.F: Relatively less expensive due to long life of pits but occupies more space so score= 2
E: One time investment with little maintenance so score=2.
DE: With variety of material used in structure the one time investment cost could be reduced and also it involves low maintenance cost so score=3.
Further reduction of cost is possible in all toilets.

7) Scalability

V.I.P and T.P.P.F: In both toilets it's difficult to empty the pit so score=1.
E and DE: Both have reduced cost but design acceptability poses a challenge so score=2.

8) Ease of construction

V.I.P and T.P.P.F: Both requires pit digging, pit-wall reinforcement, as well as reinforced concrete slabs so score =1.
E: Do not need a pit and can be constructed more quickly, but design of internal pan could be difficult, so score = 2.
DE: Needs bucket mechanism so no pit is required and design of seat is difficult, so score= 3.

9) Proneness to Flooding Risks

All of them have almost similar risk, so score 1.

C. Costing Conclusion

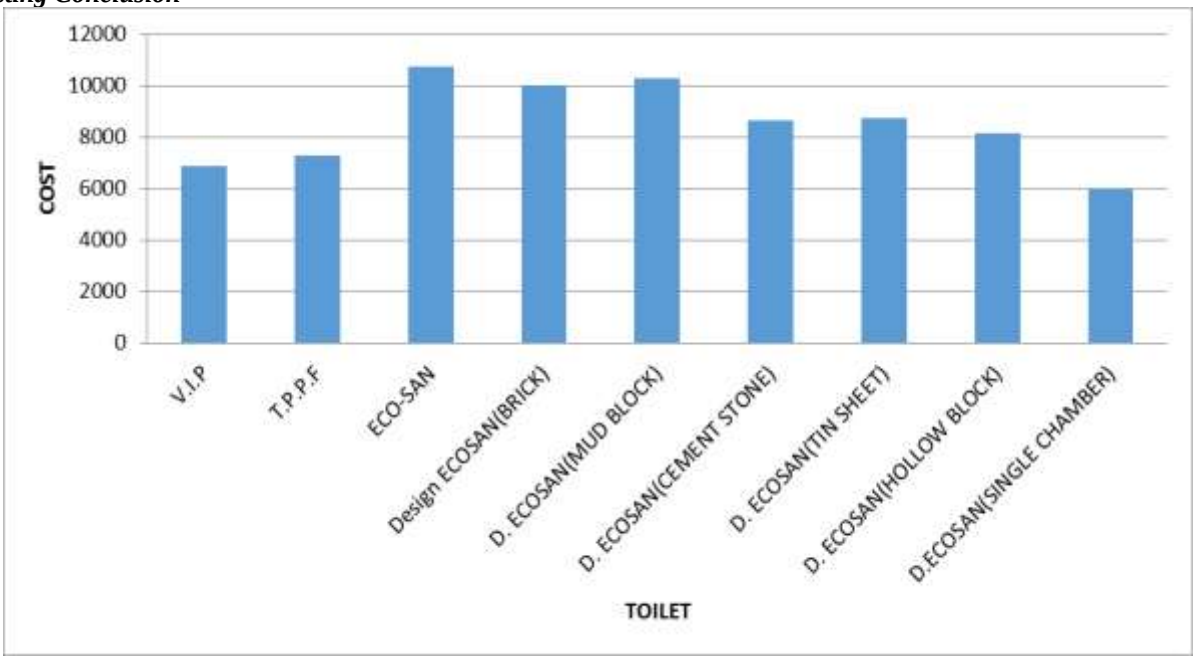

Fig. 8: Chart 6: showing cost comparison among different toilet

D. Future Scope

- More materials can be used for superstructure (cemented ply sheet, wooden superstructure, nanal bamboo superstructure, palm leaf superstructure, coconut thatches superstructure).
- Ecosan use in urban building housing.
- Use plastic for eco-san pan**.**

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